

Vacuum Potentials for the Two Only Permanent Free Particles, Proton and Electron. Pair Productions

J.X. Zheng-Johansson

Institute of Fundamental Physics Research, 611 93 Nyköping, Sweden

Abstract.

The two only species of isolatable, smallest, or unit charges $+e$ and $-e$ present in nature interact with the universal vacuum in a polarisable dielectric representation through two uniquely defined vacuum potential functions. All of the non-composite subatomic particles containing one-unit charges, $+e$ or $-e$, are therefore formed in terms of the IED model of the respective charges, of zero rest masses, oscillating in either of the two unique vacuum potential fields, together with the radiation waves of their own charges. In this paper we give a first principles treatment of the dynamics of charge in a dielectric vacuum, based on which, combined with solutions for the radiation waves obtained previously, we subsequently derive the vacuum potential function for a given charge q , which we show to be quadratic and consist each of quantised potential levels, giving therefore rise to quantised characteristic oscillation frequencies of the charge and accordingly quantised, sharply-defined masses of the IED particles. By further combining with relevant experimental properties as input information, we determine the IED particles built from the charges $+e, -e$ at their first excited states in the respective vacuum potential wells to be the proton and the electron, the observationally two only stable (permanently lived) and "free" particles containing one-unit charges. Their antiparticles as produced in pair productions can be accordingly determined. The characteristics of all of the other more energetic non-composite subatomic particles can also be recognised. We finally discuss the energy condition for pair production, which requires two successive energy supplies to (1) first disintegrate the bound pair of vaculeon charges $+e, -e$ composing a vacuon of the vacuum and (2) impart masses to the disintegrated charges.

1. Introduction

Up to the present several hundreds of isolatable subatomic particles along with their antiparticles have been discovered, of these the very energetic and (or) short lived ones existing only in high energy accelerators and cosmic ray radiation[1]. Of these observational particles, the proton (E Rutherford, 1919[1]) and the electron (J J Thomson, 1897[1]) are the only two particle species containing one-unit charges which are stable, or permanently lived, and "free" (i.e. available for building the usual materials with no need of "extraction") in the vacuum; they are the building constituents of all atoms. While conceding such "privileged" status only to these two particular opposite charged particles, nature differentiates the two by unequal masses, with the proton being about 1836 times heavier than the electron. Nature differentiates their opposite charged antiparticles, antiproton and positron, with a similar mass asymmetry, and nevertheless appears to admit both with a similar permanent lifetime expectation. Although, if pair productions are the only sources of their creations in the real physical world, the antiprotons would appear to be prominently missing, and the positrons appear to be similarly missing, or "hidden" in the vacuum. The fundamental reason for this selective, asymmetric preference of nature for our physical world is up to the present not explained.

This selective, asymmetric characteristic of the particle system has been one essential constraint imposed from the beginning upon the construction of an *internally electrodynamic* (IED) *particle model* and *vacuonic vacuum structure*, which the author carried out in recent work [2]-[16] based on overall relevant experimental observations as input information. According to the construction, briefly, a single-charged matter particle like the electron, proton, etc., is composed of (i) a point-like charge (as source) of a zero rest mass but of an oscillation of characteristic frequency and (ii) the electromagnetic waves generated by the oscillating charge. And the vacuum is filled of electrically neutral but polarisable building entities, vacuons (to be detailed in Sec. 4), separated at a mean distance b_v ; this vacuum is an electrically polarisable dielectric medium. Representations of the IED particle based mainly on solutions for the electromagnetic wave component have been the subjects of previous investigations [2]-[15], which have yielded predictions of a range of the long established basic properties and relations of particles under corresponding conditions.

In this paper, in terms of first principles solutions for the charge to be obtained first (Sec. 2) and for the electromagnetic wave component of an IED particle obtained previously [2]-[6] we formally derive in Sec. 2 the vacuum potential function for a specified charge q . Further combining with relevant experimental properties for particles as input information, we parameterise the vacuum potential functions for the two unit charges $+e, -e$, and determine accordingly the dynamical states of the two only stable, "free" particles formed therein out of the two respective charges, the proton and electron, and their antiparticles; and we elucidate the characteristics of the remaining, more energetic subatomic particles containing one-unit charges (Sec. 3). Finally, we establish the vacuonic potentials and elucidate the energy condition for pair production (Sec. 4).

2. Vacuum potential functions of charges $+e, -e$

We consider a substantial vacuum constituted of vacuons densely packed relative to one another [2, 9, 10] as represented in a three-dimensional flat euclidean space (\mathbf{R}^3), spanned here by three Cartesian coordinates X, Y, Z fixed in the vacuum. Let a charge q of zero rest mass be located at $\mathbf{R}_q(X_q, Y_q, Z_q)$ in an interstice i of the vacuons. Suppose that the charge had been continuously driven for a finite duration $-\Delta t'$ in past time, up to the present time $t = 0$, by an alternating force \mathbf{F}_{a0} of an angular frequency Ω and, in addition, a unidirectional force \mathbf{F}_{u0} in the X direction here, into possession of a total Hamiltonian ε_q . Suppose that the charge is for the present prevented from radiating; and from time $t = 0$, the initial applied force $\mathbf{F}_{app.0} (= \mathbf{F}_{a0} + \mathbf{F}_{u0})$ has ceased action. Therefore, from $t = 0$, the charge will tend to move spontaneously, say making a displacement $\mathcal{U}_q(t) = \mathbf{R}_q(t) - \mathbf{R}_i$ at time t from its equilibrium position, \mathbf{R}_i , with the same frequency (Ω) as its driving force. A (spontaneous) inertial force $\mathbf{F}_{ine} (= \mathbf{F}_{app.0})$ is therefore according to Newton's law of inertia associated with $d_t^2 \mathcal{U}_q (= \frac{d^2 \mathcal{U}_q}{dt^2})$, as $\mathbf{F}_{ine} = \mathfrak{M}_q d_t^2 \mathcal{U}_q$, where \mathfrak{M}_q is a proportionality constant, or the "(dynamical) inertial mass" of q .

In the vacuonic vacuum, the motion of the charge q is resisted. This is as a consequence that the vacuons become polarised about q and builds with q an interaction potential, $V_{vq}(\mathbf{R}_q) = V_{vq0} + \sum_n \frac{1}{n!} \nabla^n V_{vq}(\mathbf{R}_i) \mathcal{U}_q^n$, where $V_{vq0} = V_{vq}(\mathbf{R}_i)$ is the minimum value of V_{vq} ; V_{vq} is the superimposed result of the electrostatic interactions V_{vjq} of q with all of individual polarised vacuons j up to an intermediate range about q , $V_{vq}(\mathbf{R}_q) = \sum_j V_{vjq}$ (see further Sec. 4 and Appendix A). The corresponding restoring force is $\mathbf{F}_{res} = -\nabla V_{vq}(\mathbf{R}_q) - 0$. On equal footing with the fact that radiation fields of an accelerated charge, as the q here, ordinarily obey the linear Maxwell's equations and are accordingly linear, $\mathcal{U}_q (< \frac{b_v}{2})$ therefore follows to be generally relatively small. So, as it suffices, retaining the first two leading terms only, with odd terms vanishing for an isotropic vacuum, the $V_{vq}(\mathbf{R}_q)$ and \mathbf{F}_{res} are thus given

as, assuming for the illustration below along the Z direction and hence $\mathcal{U}_q(=z) = Z_q - Z_i$,

$$V_{vq}(\mathcal{U}_q) = V_{vq0} + \frac{1}{2}\beta_q \mathcal{U}_q^2, \quad \beta_q = \nabla^2 V_{vq}, \quad F_{res} = -\beta_q \mathcal{U}_q. \quad (1)$$

The charge q is by construction point like relative to its radiation waves, but is extensive across each interstice of the vacuums of a size $\sim b_v$. The latter extensive feature is requisite in order to conform to the overall basic experimental properties of charge, including spin as represented in [2] and the quantisation of energy to be elucidated below; an extensive q will be mainly involved in this paper. Concretely, q is a spinning liquid-like entity, or whirlpool, extending across the interstice region $(-\frac{b_v}{2}, \frac{b_v}{2})$ of vacuums [2, 16]; $b_v \approx 1 \times 10^{-18}$ m by a crude estimate based on experiment[17]. Let this minute extensive spinning q be described by a (normalised) probability density $\rho_q(z, t) = |\psi_q(z, t)|^2$ along the z direction here. $\rho_q(z, t)$ is associated with a density flow in the z direction here, $j_q = v_q \rho_q$ that is complex for the ψ_q being complex, v_q being the flow velocity. Alternatively, j_q is according to Appendix B a diffusion current $j_q = -D_q[(\nabla \psi_q^*)\psi_q - \psi_q^*(\nabla \psi_q)]$, where $D_q = \frac{i\hbar}{2\mathfrak{M}_q}$ is an imaginary diffusion constant.

We are here mainly interested in the formation of stable particles (or particle states) from the charge and therefore the stationary states of the charge. To attain such states, the minute extensive charge must necessarily move as a whole as a rigid object. This will be ensured if ρ_q fulfils the continuity equation,

$$\partial_t \rho_q + \nabla(\rho_q v_q) = 0 \quad \text{or} \quad \partial_t \rho_q - D_q[(\nabla^2 \psi_q^*)\psi_q - \psi_q^*(\nabla^2 \psi_q)] = 0. \quad (2)$$

Under the condition (2), and generally also in the presence of an external (total) force \mathbf{F}_{ext} , the equation of motion of the minute charge from time $t = 0$ is given according to Newton's second law as $\mathbf{F}_{ine} - \mathbf{F}_{res} + \mathbf{F}_{ext} = 0$, or,

$$d_t^2 \mathcal{U}_q + \omega^2 \mathcal{U}_q + \mathbf{F}_{ext}/\mathfrak{M}_q = 0, \quad \omega = \gamma \Omega, \quad \Omega = \sqrt{\beta_q/\mathfrak{M}_q}, \quad (3)$$

where $\gamma = 1/\sqrt{1-v^2/c^2}$ given by the solution for the electromagnetic waves radiated by the charge [2],[4].

In an ordinary environment there always present certain random radiation fields, which can statistically act (a) a torque $\mathbf{F}_{ran} \times \mathbf{d}$ on the oscillating-charge dipole, and (b) a linear force \mathbf{F}_{ran} on the charge's mass centre. Due to (a), \mathcal{U}_q may alter in orientation at every brief yet finite time interval, and will explore all orientations over long time. Due to (b), the charge may be promoted to hop over an energy barrier Δ_{vi} to a neighbouring site, randomly in any possible directions. An applied unidirectional force (F_u), here the F_{u0} acted up to initial time $t = 0$ in the X direction earlier, will ordinate q to hop in the X direction, with a mean velocity given by $v = \frac{1}{N} \sum^N \frac{X_{i+1} - X_i}{\delta t_i}$, δt_i being the dwelling time at site i . The \mathbf{F}_{ran} above, the \mathbf{F}_{app} earlier, and the \mathbf{F}_{rad} of Appendix C later are all contributions to \mathbf{F}_{ext} .

We below consider first the pure dynamics of the charge about the fixed site \mathbf{R}_i , and thus set $F_{ext} = 0$. Equation (3), to consider first, has a general solution of complex harmonic oscillation

$$\mathcal{U}_q^c(t) = \mathcal{A}_q \theta_q(t), \quad \theta_q(t) = e^{i(\omega t + \alpha_o)}; \quad \mathcal{U}_q(t) = \text{Re}[\mathcal{U}_q^c(t)]; \quad (4)$$

i.e., in zero applied field the minute charge as a whole executes a harmonic motion of displacement \mathcal{U}_q in the quadratic potential well V_{vq} . The corresponding kinetic and elastic potential energies are thus $\varepsilon_{qk}(t) = \frac{1}{2}\mathfrak{M}_q \dot{\mathcal{U}}_q^2$ and $\mathcal{V}_q(t) = V_{vq}(\mathcal{U}_q(t)) - V_{vq0} = \frac{1}{2}\gamma\beta_q \mathcal{U}_q^2(t)$; and the total mechanical energy, or total Hamiltonian, is

$$\varepsilon_q(t) = \varepsilon_{qk}(t) + \mathcal{V}_q(t) = \varepsilon_q |\theta_q(t)|^2 = \varepsilon_q, \quad \varepsilon_q = \frac{1}{2}\gamma\mathfrak{M}_q \Omega^2 \mathcal{A}_q^2, \quad (5)$$

where $|\theta_q(t)|^2 = 1$; (5) defines a stationary state for the harmonically oscillating charge.

The constraining equation (2) decomposes into two conjugate second order differential equations for ψ_q and ψ_q^* , that are mathematically equivalent to the Schrödinger equations for a harmonic oscillator. The solution for ψ_q (and similarly ψ^*) follows to be the standard hermit polynomial (e.g. [18]). And the energy solution, restricting for simplicity here to the excitations which create matter particles only, consists of quantised levels,

$$\varepsilon_{qn} = n\hbar\omega, \quad n = 1, 2, \dots \quad (6)$$

where a mathematically permitted term $\frac{1}{2}\hbar\omega$ is not physical and thus dropped based on a comparison with the empirical Plank energy equation for radiation. (6) is a prediction of the Planck energy equation for the electromagnetic radiation associated with the ε_q here, and hence the mass m of the resulting IED particle to be specified below.

The charge in oscillatory motion normally will generate electromagnetic waves, gradually and thus continuously so as for the total system to manifest wave phenomena. The oscillating charge and its radiation fields together make up our *IED particle*. If the charge is let emit radiation only and (re)absorb none, after a time t_φ its entire ε_q will thus have been converted to the total energy $\varepsilon'' (= \sqrt{\varepsilon''^\dagger \varepsilon''^\ddagger}) = \varepsilon_q$ of electromagnetic wave, which consists of two Doppler-effected opposite travelling components E^\dagger, E^\ddagger , of total $E = E^\dagger + E^\ddagger$ along a wave path, and extends a wave train of a mean total length L_φ . ε'' is given according to electromagnetic theory as $\varepsilon'' = L_\varphi \epsilon_0 \gamma |E|^2$. Alternatively, from the perspective that they have a mean linear momentum $p'' = \varepsilon''/c = \hbar k$, with $k = \omega/c$, the electromagnetic waves are as if a rigid wave train travelling rectilinearly at the speed of light c here in an elastic vacuum. The same ε'' is thus now given [2, 4, 6] as the kinetic energy, $\varepsilon_k = \frac{1}{2}m''c^2$, of the wave train plus an elastic potential energy equal to ε_k , whence $\varepsilon'' = 2 \times \varepsilon_k = m''c^2$, where m'' is the relativistic mass of the wave train and, equivalently (see e.g. [4]), of the IED particle.

The ε'' above and the Newtonian result ε_q of (5), being equal to ε_{qn} each, follow therefore to be each quantised, in the inevitable way as

$$\varepsilon'' \rightarrow \varepsilon_n = L_\varphi \epsilon_0 E_n = m_n c^2, \quad \text{with } E'' \rightarrow E_n = \sqrt{n} E_1, \quad m'' \rightarrow m_n = nm, \quad (7)$$

$$\varepsilon_q \rightarrow \varepsilon_{qn}^{newt} = \frac{1}{2} \gamma \beta_q \mathcal{A}_{qn}^2, \quad \text{with } \mathcal{A}_q \rightarrow \mathcal{A}_{qn} = \sqrt{n} \mathcal{A}_{q1}, \quad (8)$$

and $\beta_q = \mathfrak{M}_q \Omega^2$ as given by (3c). From the equalities $\varepsilon_n = \varepsilon_{qn}^{newt} = \varepsilon_{qn}$, we obtain

$$\omega = \frac{mc^2}{\hbar}, \quad \mathcal{A}_{q1} = \left(\frac{2Mc^2}{\beta_q} \right)^{1/2}, \quad \text{or } \beta_q = \frac{2Mc^2}{\mathcal{A}_{q1}^2}, \quad \mathfrak{M}_q = \frac{2Mc^2}{\Omega^2 \mathcal{A}_{q1}^2}, \quad (9)$$

where $m \equiv m_1 = \gamma M$ is the relativistic mass and $M = \lim_{v^2/c^2 \rightarrow 0} m$ the rest mass of the IED particle formed of the charge q at the energy level $n = 1$ of excited state.

Any massive materials in ordinary conditions in the surrounding will serve as non "absorbing" reflection walls to the wave of the energy quanta $n \times \hbar\omega$ which can only be annihilated through pair processes. So from the nearest such walls the waves will be reflected back to the charge, be re-absorbed by it and then re-emitted, continuously and repeatedly. The total energy ε_{tn} of the IED particle is at any time carried a fraction a_1 by the charge and a fraction a_2 by the radiation wave, with $0 \leq a_1, a_2 \leq 1$, $a_1 + a_2 = 1$. So $\varepsilon_{tn} = a_1 \varepsilon_{qn} + a_2 \varepsilon_n$; ε_{tn} is quantised. Accordingly, the actual potential of the charge is at any time a fraction a_1 of the total V_{vqn} , $a_1 V_{vqn}$; and this, as one will readily obtain by combining with the solution of Appendix C[16], is as a result that \mathcal{A}_{q1} is scaled by $\sqrt{a_1}$ to $\sqrt{a_1} \mathcal{A}_{q1}$. For the charge dynamics in connection to vacuum potential as the major concern below, we shall for simplicity return to the extreme situation of $a_1 = 1$, $a_2 = 0$.

With $\mathcal{A}_q \rightarrow \mathcal{A}_{qn}$ of (8b), we have $\mathcal{U}_q \equiv z \rightarrow \mathcal{U}_{qn} \equiv z_n = \sqrt{n}z$, $z = \mathcal{A}_{q1}\text{Re}[\theta_q]$; or $\zeta_n = \frac{z_n}{b_v} = \sqrt{n}\zeta$, $\zeta = \frac{z}{b_v}$. Placing this \mathcal{U}_{qn} in (1a), we obtain the quantised vacuum potential of charge q

$$V_{vqn}(z) = V_{vq0} + \frac{1}{2}\beta_q n z^2 = V_{vq0} + \frac{1}{2}\beta'_q n \zeta^2 \quad (|z| < \frac{b_v}{2}) \quad (10)$$

where $\beta'_q = b_v^2 \beta_q$. The β_q and V_{vq0} are fixed for a fixed q value and the universal dielectric vacuum, if we disregard possible effects on the local instantaneous vacuum configurations from the variant sizes and frequencies of the charge. V_{vqn} thus is an apparently uniquely defined function for a specified q . The two only isolatable, smallest or unit charges $+e$ and $-e$ present in nature therefore are associated with two unique vacuum potential functions.

3. Parameterisation of potential functions. Vacuum potentials for p, e, \bar{p}, \bar{e}

At the present we lack adequate input data, the vacuum polarisability especially (see Appendix A), for an *ab initio* evaluation of V_{vq} . Instead, we shall below determine the parameters β_q, V_{vq0} of the V_{vq} function for charges $+e, -e$ based on experimental properties for particles, specifically the two most common particles proton (p) and electron (e) mainly. The parameterised potentials will in the end be characteristically justified by comparison with the direct electromagnetic interaction functions for an external q and individual vacuum given in Appendix A based on an assumed polarisability.

Observationally (e.g. [1]), the p, e are (I) of sharply-defined constant rest masses M_p, M_e , (II) of the smallest masses (i.e. the M_p, M_e) among the particles which contain each one-unit $+e$ or $-e$ and also possess the properties (III)-(IV) below, (III) stable (i.e. of infinite lifetimes), and (IV) free in the vacuum in the sense that they are available for building the materials in our physical world with no need of extra energy for extraction. The oscillating charges $+e, -e$ composing the corresponding two IED particles are therefore required to be (i) stationary, i.e. being at one of the energy levels $n = 1, 2, \dots$ following (6), (ii) factually at level $n = 1$ in accordance to property (II), (iii) of infinite lifetimes, and (iv) free in the vacuum. (iii) is to be justified and (iv) to be furnished by positioning of the level $n = 1$ below.

It follows from Appendix C that the time required for the (quasi) harmonically oscillating charge q at the initial state $n = 1$ to have emitted its entire one energy quantum $\varepsilon_{q1} - \varepsilon_{q0}$, and transformed to the final state $n = 0$, is given after (C.3) as

$$t_{\varphi 1.0} = \infty. \quad (11)$$

By the usual quantum mechanical principle a transfer of only a fraction of a quantum $\hbar\omega$ from one charge q to another charge q' in their quantum states is forbidden, therefore a transition of charge q from level $n = 1$ to 0 within a finite time is improbable; this verifies the (iii) above. This restriction however does not apply if q is in an asymmetric potential field, e.g. one produced by the charge (q') of an antiparticle at a very close distance.

We define a "vacuum level", $V_{vqv} = V_{vqn}(z_v)$, as the level at which the pair of vacuons constituting a vacuum are no longer attracted with one another, thus being (effectively) at an infinite separation. Accordingly, at this level an external charge q , oscillating at amplitude z_v about its equilibrium position $z = 0$, just begins to be no longer attracted to the surrounding vacuons[‡], but is subject to instantaneous collisions with the vacuons only. Therefore, a charge q at the vacuum level is free in the sense of (IV). The charges $+e, -e$ of the p, e of the feature (iv) are therefore at the vacuum level; and they are in turn in their $n = 1$ stationary states as stated by (ii)-(iii). That is, for the charges of p, e , the

[‡] A "negative" V_{vq0} strictly applies to $+q$ and has for $-q$ a relative meaning only due to the V_{vq} asymmetry over $+q$ and $-q$; see further Appendix A.1.

$n = 1$ levels coincide with the vacuum level, $V_{vq1} = V_{vqv} = 0$, and $z_v = \mathcal{A}_{q1}$, whence (iv) is furnished.

By the solution (6), in zero external field the harmonic state of the charge at level $n = 1$ can only be promoted to higher levels by a discrete amount at a time, i.e. $n\hbar\omega$, $n = 2, 3, \dots$; or it will not be altered at all. The charge is however not restricted from being continuously promoted to higher energies if acted on by an unidirectional force F_u and, assuming a sufficiently large F_u , may be driven momentarily to the mid point $z_{1/2} = (Z_{i+1} - Z_i)/2$ between site i and adjacent site $i + 1$ along a diffusion path. At $z_{1/2}$, it experiences shortest distances to the neighbouring vacuums, and therefore a maximum potential $V'_{vq1m} = V'_{vq1}(z_{1/2})$. The potential difference $\Delta_{v1}(z) = V'_{vq1}(z) - V_{vq1}$ defines an energy barrier which the charge q must overcome to hop to an adjacent site, see Figure 1. Its height $\Delta_{v1}(z_{1/2}) = V'_{vq1m} - V_{vq1}$ and width, δ_1 , are both dependent on the instantaneous interaction of q , while at $z_{1/2}$, with the vacuums which have fluctuating configurations due to the influence of the random environmental fields and the instantaneous motion of the charge q ; their determination is beyond the scope of this paper.

In conformity with the observational vacuum, the vacuums are densely packed in a disordered fashion and, owing to the vacuum structure, are in zero external field electrically neutral and non interacting, whence forming a perfect liquid[2]. The V_{vqn} is intermediate ranged (see Appendix A); the vacuums thus to good approximation present to q with an average structure. In the latter regard, and provided disorder effect is to be superimposed where in question (such as diffusion path), we may represent the vacuums, as a simplest illustration, as arranged on a simple cubic lattice of spacing b_v . Accordingly, $z_{1/2} = \frac{b_v}{2}$; and the oscillation amplitude of the charge q at $n = 1$ level is

$$\mathcal{A}_{q1} = \frac{1}{2}(b_v - \delta_1) \quad (12)$$

With this \mathcal{A}_{q1} , and the experimental rest masses of p and e , $M_p (= 938.27 \text{ MeV})$ and $M_e (= 0.511 \text{ MeV})$ for M in (9c), we obtain for the charges $+e$ and $-e$:

$$\beta_q = \frac{2Mc^2}{(f_1 b_v/2)^2}, \quad f_1 = \frac{\mathcal{A}_{q1}}{b_v/2} = 1 - \frac{\delta_1}{b_v} \quad (q, M = +e, M_p; -e, M_e) \quad (13)$$

Values of β_q evaluated based on (13) for the charges of the IED proton p , electron e , antiproton \bar{p} , and positron \bar{e} , together with other parameters involved in this section, Ω , $\mathcal{A}_{q1}(\mathcal{A}_{q\alpha})$, \mathfrak{M}_q , $t_{\varphi 1.0}$, are tabulated in Table 1.

Table 1.

$q^{(a)}$	IED Particle	$M^{(a)}$ (MeV)	$\Omega^{(b)}$ (10^{20} r/s)	$\mathcal{A}_{q1} f_1^{(c)}$ (10^{-18} m)	$\beta_q f_1^2^{(d)}$ (10^{23} N/m)	$\mathfrak{M}_q f_1^2^{(e)}$ (kg)	Lifetime ^(f) (s)
$+e$	p	$(M_p) 938.27$	14280	0.5	12020	5.896×10^{-22}	∞
$-e$	\bar{p}	$(M_{\bar{p}}) 938.27$	14280	21.42	6.549	3.218×10^{-25}	(short)
$-e$	e	$(M_e) 0.511$	7.778	0.5	6.549	1.083×10^{-18}	∞
$+e$	\bar{e}	$(M_{\bar{e}}) 0.511$	7.778	0.0116	12020	1.989×10^{-15}	(∞)

(a) Experimental masses of p, \bar{p}, e, \bar{e} [1]. (b) After (9a). (c) Given by (12) for p, e and (16), (17) for \bar{p}, \bar{e} . (d) After (13a). (e) After (3c). (f) From (11) for p, e and the discussions before (16) and after (17) for \bar{e} and \bar{p} .

Taking (i)-(iv) together, the creation of particle p or e corresponds to the excitation from energy level $n = 0$ (the ground state) to $n = 1$ (the first excited state) of the charge $q = +e$ or $-e$ in its potential well V_{v+en} or V_{v-en} , upon a minimum external energy supply $\varepsilon_{exc.m} (= \hbar\omega_\gamma) = \varepsilon_{q1} = M_p c^2$ or $M_e c^2$. $\varepsilon_{exc.m}$ is thus used for overcoming the potential difference $V_{vq0} - V_{vq1} = V_{vq0} - 0$, whence

$$V_{vq0} = -\varepsilon_{exc.m} = -Mc^2 \quad (q, M = +e, M_p; -e, M_e) \quad (14)$$

And the energy ε_{q1} gained by the charge $+e$ or $-e$ corresponds to the total energy associated with the rest mass M_p or M_e of the resulting IED particle p or e .

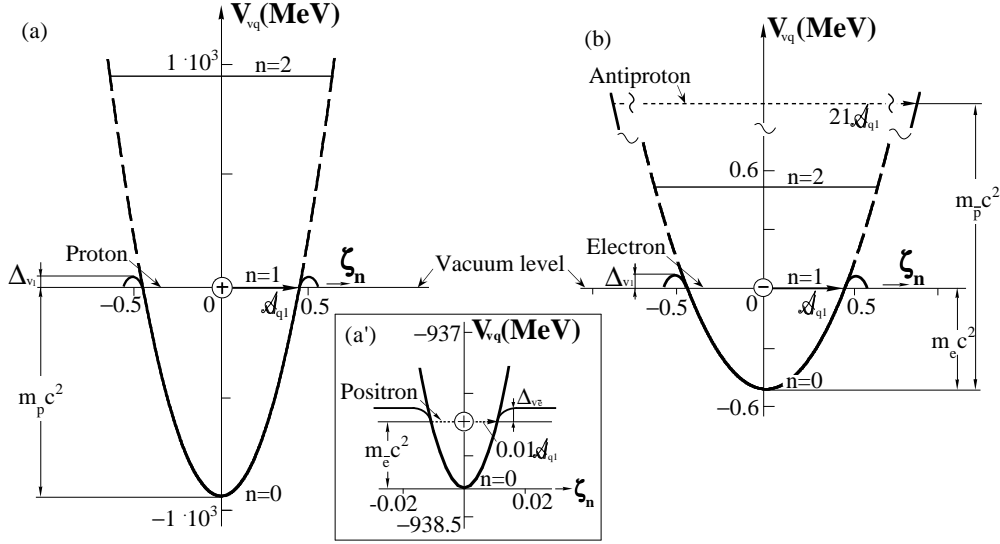


Figure 1. Vacuum potential functions $V_{vq}(\zeta_n)$ versus ζ_n given by (15) for (a) charge $+e$, and (b) charge $-e$. Used for the plot: $f_1 = 0.9$.

Placing (13a),(14) in (10), we obtain the parameterised quantised vacuum potentials of the charges $+e$ and $-e$ respectively versus $\zeta_n (= \sqrt{n}\zeta)$ across the interstice about $\zeta_n = 0$,

$$V_{vqn}(\zeta_n) = Mc^2 \left(-1 + \frac{4}{f_1^2} \zeta_n^2 \right) \quad (q, M = +e, M_p; -e, M_e; |\zeta| < \frac{1}{2}). \quad (15)$$

The function V_{vqn} is completely specified by (15) except for f_1 that depends on δ_1 through (13b) and is yet to be determined. f_1 affects the steepness of the V_{vqn} well only; the energy levels of stable particle species (or particle states) therefore are completely specified by (15).

Equations (15), see also the graphical plots in Figure 1a,b, show a strong asymmetry of $V_{vqn}(\zeta_n)$ with respect to an external charge $+e$ and $-e$: $V_{v+en}(\zeta_n)$ has a strongly negative depth $-M_p c^2 = -938.27$ MeV (Figure 1a), and V_{v-en} has a shallow "negative" depth $-M_e c^2 = -0.511$ MeV (Figure 1b). This very asymmetry will be directly demonstrated in Appendix A.1 through a formal evaluation of the electromagnetic interaction for an external q charge and vacuum: an external positive charge $+q$ will be strongly attracted by the vacuum, while a negative charge $-q$ be strongly repelled therein. And this is a direct consequence of the asymmetric structure of the vacuum, of which $-e$ envelops $+e$ (see Sec.4), combined with a "strong force" effect which onsets at short interaction distances compared to the extension of the vacuum.

As already entered as an input for the V_{vqn} parameterisation, the proton lies at the first excited stationary state, i.e. energy level $n = 1$, of charge $+e$ in the V_{v+en} well, and the electron at level $n = 1$ of $-e$ in the V_{v-en} well, shown by the solid horizontal lines in Figure 1a and b. The very large mass ratio of p over e , $M_p/M_e \approx 1836$, in retrospect, is a direct reflection of the asymmetry of the two vacuum potentials.

Based on the solutions (6), there is no stationary state below the level $n = 1$ for either charge. However, in a pair production out of a vacuum (Sec. 4) in the vacuum, both its bound vaculeon charges $+e$ and $-e$ (assuming having been firstly disintegrated and now serving as two un-bound external charges) are by a resonance condition (see the end of Sec. 4) simultaneously excited with equal energies, provided a total energy $2 \times \varepsilon_{exc} = 2 \times \hbar\omega_\gamma$ is externally supplied. If ε_{exc} is such that $-e$ is excited to its $n = 1$ level in the V_{v-en} well (Figure 1b), whence $\omega_\gamma = M_e c^2 / \hbar$ and the creation of a stable electron e , then $+e$ is excited by the same quantum $\hbar\omega_\gamma$ in the V_{v+en} well (Figure 1a'), whence the creation of a positron \bar{e} . The $+e$ of \bar{e} is at the level $V_{v+e\bar{e}} = V_{v+en}(\mathcal{A}_{+e\bar{e}})$ (dotted horizontal line in Figure 1a')

and has an oscillation amplitude $\mathcal{A}_{+e\bar{e}}$. This \bar{e} state is far below the $n = 1$ (proton) level in the V_{V+en} well, and is not a stationary state. But it would be virtually stable if, as is highly probable, the e simultaneously created has moved away and also no other electron presents nearby for annihilation. This \bar{e} will be "hidden" in the vacuum and not "free" in the sense said in (IV) earlier.

On the other hand, this excited $+e$ of \bar{e} is free to travel from site to site at its own constant potential level $V_{V+e\bar{e}}$, provided it has a sufficient kinetic energy to "hop" over a barrier (cf Figure 1a'), $\Delta_{V\bar{e}} = V'_{V+e\bar{e}}(z) - V_{V+e\bar{e}}(\mathcal{A}_{q\bar{e}})$, crossing each two sites. The $\mathcal{A}_{+e\bar{e}}$ of $+e$ may be evaluated based on the energy equation for \bar{e} , $\frac{1}{2}\beta_{+e}\mathcal{A}_{+e\bar{e}}^2 = M_e c^2$, given by using $\beta_q = \beta_{+e}$ for $+e$ in (13) but with the ε_{exc} equal to that of its opposite charge at level $n = 1$ (i.e. $M_e c^2$) for ε_{q1} , to be

$$\mathcal{A}_{+e\bar{e}} = \sqrt{2M_e c^2 / \beta_{+e}} = \sqrt{(M_e / M_p)} \mathcal{A}_{+e1} = 0.0116 \mathcal{A}_{+e1}, \quad (16)$$

which is exceedingly small. The width of the barrier $\Delta_{V\bar{e}}$, $\delta_{\bar{e}} = b_v - 2 \times 0.01 \mathcal{A}_{q1} \sim b_v$ (assuming $\delta_1 \ll \frac{b_v}{2}$), is thus wide. So after excited to above the barrier $\Delta_{V\bar{e}}$, the charge will be translating across the large distance $\delta_{\bar{e}} \sim b_v$ before entering next V_{V+en} well. From the experimental decay processes of the subatomic particles (e.g. [1]), we observe that, if disregarding the mediators W^\pm , \bar{e} is in fact the only non-composite particle formed of $+e$ which is below the $n = 1$ level in the V_{V+en} well. All of the other mass-deficit subatomic particles like π^+ , K^+ , ρ , manifestly having one-unit charges $+e$'s, are apparently composite particles built ultimately of a lepton μ and its neutrino, with μ being built of charge $-e$ in the V_{V-en} well.

If on the other hand ε_{exc} is such that $+e$ is excited to the $n = 1$ level in the V_{V+en} well (Figure 1a), whence $\omega_\gamma = M_p c^2 / \hbar$ and the creation of a stable proton p , then similarly by a resonance condition $-e$ is simultaneously excited by the same energy in the V_{V-en} well (Figure 1b), whence the creation of an antiproton \bar{p} . The charge $-e$ of \bar{p} is at the potential level $V_{V-e\bar{p}} = V_{V-en}(\mathcal{A}_{e\bar{p}})$ (dotted horizontal line in Figure 1b) and has an oscillation amplitude $\mathcal{A}_{e\bar{p}}$. Similarly from $\frac{1}{2}\beta_{-e}\mathcal{A}_{e\bar{p}}^2 = M_p c^2$ given by using $\beta_q = \beta_{-e}$ in (8) and $\varepsilon_{exc} = M_p c^2$, we formally obtain

$$\mathcal{A}_{e\bar{p}} = \sqrt{2M_p c^2 / \beta_{-e}} = \sqrt{(M_p / M_e)} \mathcal{A}_{-e1} = 21.42 \mathcal{A}_{-e1}, \quad (17)$$

which is many times larger than \mathcal{A}_{-e1} of the $-e$ of an electron, as is an inevitable result for $V_{V-e\bar{p}} \gg V_{V-e1}$.

Since however the vacuum potential has a mean translation periodicity b_v along any diffusion path and thus is only quadratically well defined up to the vacuum level plus a Δ_{V_1} about $z = \frac{b_v}{2}$, the charge $-e$ of \bar{p} of the exceedingly large $\mathcal{A}_{e\bar{p}}$ factually traverses many potential wells in each quart of its oscillation period. This motion is no longer properly harmonic; and higher stationary levels than 1, i.e. $n = 2, 3, \dots$, become unphysical except during charge-vacuum head-on collisions. The charge $-e$ of \bar{p} accordingly will be so energetic as to translate swiftly across many sites in short time, meeting and scattering with other particles and losing its energy easily, until settling down at the next and actually the only lower stationary level in the V_{V-en} well, which is the $n = 1$ or electron state. That is, the resulting antiproton is short-lived and briefly will descend into a stable electron. This could explain the prominent "missing" of the antiprotons \bar{p} 's if all the protons present in nature indeed are produced in $p-\bar{p}$ pair productions.

The above scheme can similarly account for the short lifetimes of the other observational heavier-mass, non-composite subatomic particles made of one-unit charges, actually the leptons μ, τ only which are built of one-unit $-e$ in the V_{V-en} well, if disregarding the mediators, similarly based on the experimental decay processes of subatomic particles. All the other heavier-mass baryons such as Ω^- , Λ 's, Σ 's and mesons such as π^- , D^\pm , etc. having

either one-unit $-e$ or (as earlier remarked) $+e$, are apparently composite particles ultimately built of μ 's and their neutrinos.

4. Vacuonic potentials. Possible scheme for pair production

A vacuon (e.g. v_1 in Figure 2a) by construction[2, 9] consists of a positive charge $+e$ seated on a minute sphere of radius r_{p_v} at the centre, and a negative charge $-e$ on a concentric spherical shell of thickness $2r_o$ and radius r_{n_v} about p_v , termed as a p -vaculeon (p_v) and n -vaculeon (n_v). The p_v, n_v have spins $\frac{\hbar}{2}$ each; in their bound state in a vacuon their spin magnetic moments are oriented in opposite directions in each others' magnetic fields. The vacuon structure, as a building entity of the substantial vacuum, is constructed based on overall experimental indications, most directly the pair production and annihilation experiments in particular[2, 9, 13]; see further the discussion after (20) later.

The r_{p_v}, r_{n_v} represent the most probable radii of the practically extensive p_v, n_v (similarly as the single charge q in Sec. 2) at the scale b_v , and r_o is said in a similar sense. We presently lack experimental information either on their direct values or for their theoretical evaluation; although definitely they must be (much) smaller than $\frac{b_v}{2}$. For the illustration below we shall take the r_{p_v}, r_o values by their average, $\frac{1}{2}(r_{p_v} + r_o) = \sigma$. And we set the vacuon radius $r_v = r_{n_v} + r_o$, as the contact radius of the vacuons on a simple cubic lattice (Sec. 3), so $r_v = \frac{b_v}{2}$, see Figure 2a. The focus of our discussion below will be to demonstrate the characteristics of the interactions rather than to perform an accurate numerical calculation.

In zero external field, the two vaculeon charges $+e$ and $-e$ of a vacuon, say the v_1 at $z = 0$ in Figure 2a, interact each other by a Coulomb attraction, $\mathcal{V}_{p_v n_v}^{coul} = -\frac{e^2}{4\pi\epsilon_0 r} = u_0 \frac{r_v}{r} = u_1 \frac{\sigma}{r}$, and a short range repulsion, $\mathcal{V}_{p_v n_v}^{rep} = gu_1 \left(\frac{\sigma}{r}\right)^N$, where $u_0 = \frac{e^2}{4\pi\epsilon_0 (b_v/2)} = 2879.9$ MeV for $r_v = \frac{b_v}{2} = 0.5 \times 10^{-18}$ m, $u_1 = u_0(r_v/\sigma)$, and $g = \frac{\pi\sigma^2}{4\pi r_{n_v}^2} = \frac{\sigma^2}{4r_{n_v}^2}$ is the fraction of charge of the segment, of size $\pi\sigma^2$ on the extensive n_v shell of an area $4\pi r_{n_v}^2$, which makes direct contact with p_v . The N, σ values are to be determined. The total p_v, n_v interaction potential energy per vaculeon is thus

$$V_{p_v n_v}(r) = \frac{1}{2}(\mathcal{V}_{p_v n_v}^{rep}(r) + \mathcal{V}_{p_v n_v}^{coul}(r)) = \frac{u_1}{2} \left[g \left(\frac{\sigma}{r} \right)^N - \frac{\sigma}{r} \right] \quad (18)$$

See also the graphical plot of $V_{p_v n_v}(r)$ in Figure 3a (solid curve 1), where $N = 12$ (Lennard-Jones' value) and $\sigma = 0.1b_v$ are used for the illustration.

At $r \gg r_{p_v}$, n_v is acted on by p_v by (mainly) an attractive force $F_{p_v n_v} = -\frac{\partial \mathcal{V}_{p_v n_v}}{\partial r} \approx -\frac{\partial \mathcal{V}_{p_v n_v}^{coul}}{\partial r}$, where $\mathcal{V}_{p_v n_v} = 2V_{p_v n_v}$. This, in the zero mass representation, is counterbalanced by a magnetic force F_m on the spinning n -vaculeon charge on the spherical envelope in the magnetic field produced by spinning motion of p -vaculeon charge (Appendix A of [2]), $F_m = -F_{p_v n_v}$. The equality defines the equilibrium radius $r_{n_v} (= \frac{b_v}{2} - \sigma)$, at which $\mathcal{V}_{p_v n_v}(r_{n_v}) = -u_1(\sigma/r_{n_v}) = -3599.9$ MeV, or $V_{p_v n_v}(r_{n_v}) = -1799.9$ MeV; accordingly, n_v has a spin kinetic energy $\mathcal{E}_{n_v k} = -\frac{1}{2}\mathcal{V}_{p_v n_v}$ and Hamiltonian $\mathcal{E}_{n_v t} = \mathcal{V}_{p_v n_v} + \mathcal{E}_{n_v k} = \frac{1}{2}\mathcal{V}_{p_v n_v}$. This $\mathcal{V}_{p_v n_v}$, of a GeV scale, is far too deep for the vaculeon pair to be disintegrated to the vacuum level, by merely a supply of an excitation energy $2\epsilon_{exc.m}$ given by (14), or

$$2 \times \epsilon_{exc} = 2 \times \hbar\omega_\gamma \geq 2 \times Mc^2 = \frac{1}{2}\beta_q(\sqrt{2}\mathcal{A}_{q1})^2 \quad (M = M_p, M_e; q = +e, -e) \quad (19)$$

which are $2 \times 938.27, 2 \times 0.511$ MeV for the $p-\bar{p}, e-\bar{e}$ pair productions. This $2\epsilon_{exc}$ is merely enough to impart masses to a pair of dissociated vaculeon charges.

Inevitably, before the condition (19) becomes legible, an additional energy, as enormous as $2 \times (V_{vq0} - V_{p_v n_v}(r_{n_v})) \sim 3600$ MeV for $e-\bar{e}$ production or 1720 MeV for $p-\bar{p}$ production,

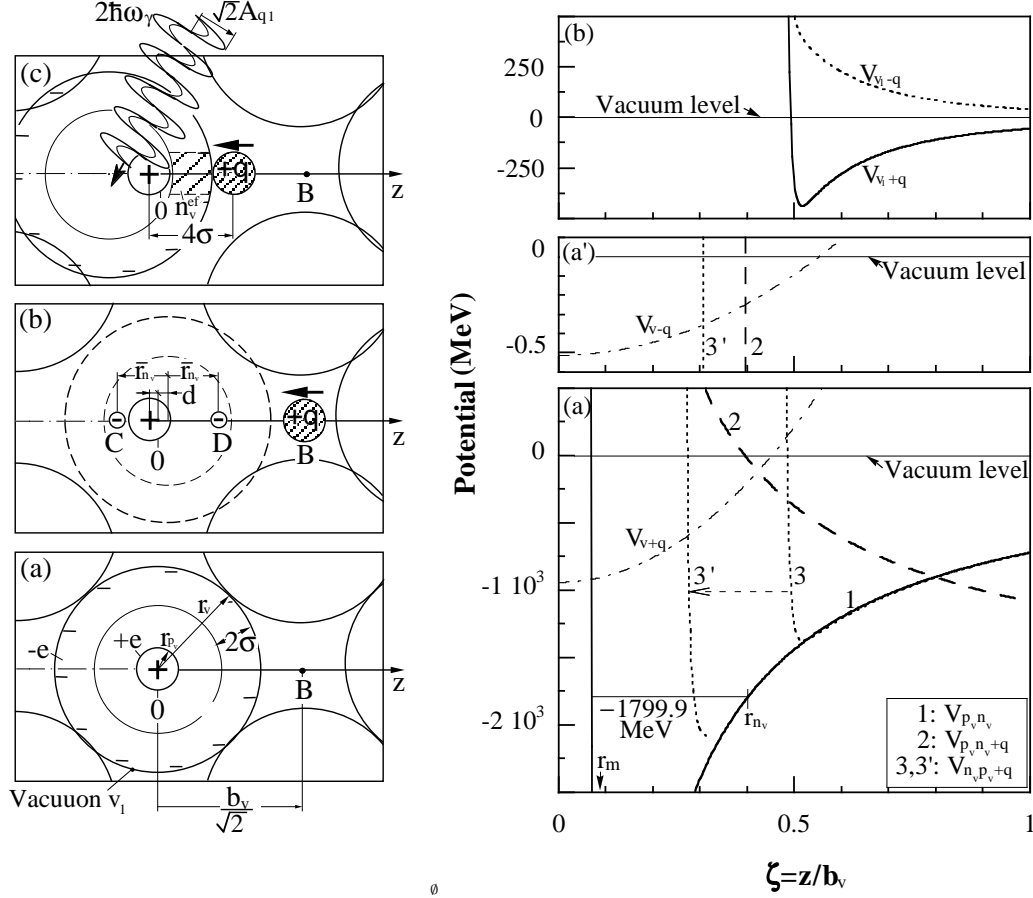


Figure 2 (left graphs). Vacuons v_i , with v_1 at $z = 0$, arranged on a simple cubic lattice (a) in zero external field, and (b)–(c) in the field of an external charge $+q$ in the interstice B ; $+q$ is moving toward v_1 at a finite velocity. In (c), $+q$ has collided with n_v and in turn knocked n_v into colliding with p_v to their closed approaches each; at the same time, a 2γ wave of energy $2\hbar\omega_\gamma (\geq 2Mc^2)$ is incident on to v_1 .

Figure 3 (right graphs). (a) Solid curve: p_v – n_v interaction potential $V_{p_v n_v}(\zeta)$ given by (18) for vacuon v_1 in zero external field (as in Figure 2a), $\zeta = r/b_v$. Dashed curve 2 and dotted curve 3 ($\zeta > r_v$): potential energies of p_v and n_v of v_1 , $V_{p_v n_v+q}(\zeta)$ and $V_{n_v p_v+q}(\zeta)$ given by (A.3)–(A.4) in the field of external charge $+q$ as in Figure 2b. The rapid rising part of curve 2 and curve 3': the two potentials $V_{p_v n_v+q}(\zeta)$ and $V_{n_v p_v+q}(\zeta)$ when $+q$, n_v and p_v are as positioned in Figure 2c. Corresponding curves 2, 3' for $-q$ are shown in (a'). Short-dot-dashed curves: the function V_{v+en} in (a) and V_{v-en} in (a') given by (14). Used for the plots: $\sigma = 0.1b_v$ (thus $u_1 = 14400$ MeV), $N = 12$, $d = 0.01b_v$. At $r_m = (gN)^{\frac{1}{N-1}}\sigma = 0.859\sigma$, $\frac{\partial V_{p_v n_v}}{\partial r} = 0$ and $V_{p_v n_v m}(r_m) = -\frac{u_1}{2}(gN)^{-\frac{1}{N-1}}[\frac{N-1}{N}] = -0.534u_1$. (b) Interaction potential V_{v_1+q} (solid curve), given by (A.2b), between vacuon v_1 and external charge $+q$ of position ζ as in Figure 2b; and V_{v_1-q} (dashed curve) between v_1 and $-q$. Values used for the plots are as in (a).

needs firstly be supplied so as to disassociate the pair of bound vaculeons of the v_1 here to at or above the ground state of the charge, V_{vq0} . Such an enormous energy may be practically supplied if the two vaculeons are simultaneously approached by a charged particle (e.g. a nucleon) q at very short distance and thereby repelled to above V_{vq0} ; an external q thus needs be in the proximity (like the $+q$ in the interstice B in Figure 2b) and moving at an adequate speed toward v_1 . A possible such process is illustrated in Figure 2c. The corresponding potentials of p_v, n_v in the presence of $+q$, of coordinate z , and similarly of $-q$, $V_{p_v n_v \pm q}(z), V_{n_v p_v \pm q}(z)$ as functions of the position z of $+q$ or $-q$ are given by (A.3)–(A.4), Appendix A.2. As the graphical plots, the dashed curves 2 and dotted curves 3 to 3' in Figure 3 a,a' directly show, the two potential functions rise each rapidly to above V_{vq0} at the closest approach between $+q, n_v$ and p_v (Figure 2c), i.e. at $z \sim 3\sigma$. The vaculeons p_v and n_v are now effectively no longer bound each other, being as if separated infinitely apart.

If these, as soon as after their dissociation, are impinged by a γ wave (see Figure 2c) of an energy $2\varepsilon_{exc} = 2\hbar\omega_\gamma$ fulfilling (19), e.g. $\omega_\gamma = m_p c^2/\hbar$, then upon absorption of $2\varepsilon_{exc}$ by a "resonance condition" (see below) the vaculeon charges $+e, -e$ will have been each endowed with an oscillation energy $\hbar\omega_p = m_p c^2$. $+e$ is now promoted to the energy level $n = 1$ in the V_{v+en} well at one site (short-dot-dashed curve in Figure 3a); and $-e$ to the level of \bar{p} in the V_{v-en} well, by a probable tendency, in another site located in the opposite direction to the displacement of $+e$, since the charges $+e, -e$ producing (or absorbing) the same radiation **E** field have opposite oscillation displacements. And similarly for $\omega_\gamma = m_e c^2/\hbar$, with the charge $-e$ promoted to level $n = 1$ in the V_{v-en} well (short-dot-dashed curve in Figure 3a'), and $+e$ to the level of \bar{e} in the V_{v+en} well. These are the $p-\bar{p}$ and $e-\bar{e}$ pair productions of the reaction equations

$$2\gamma \rightarrow p + \bar{p}, \quad 2\gamma \rightarrow e + \bar{e}. \quad (20)$$

The pair of particles produced will be at rest if $\Omega = Mc^2/\hbar$ or will have a residual velocity $v = c\sqrt{1 - 1/\gamma^2}$ if $\omega = \gamma\Omega > \Omega$, i.e. $\gamma > 1$.

The reaction equations (20), together with the preceding energy criterion (19) and the requirement for the presence of a nucleus (or nuclei) in a pair production, are in complete agreement with experiment. Entirely as an experimental reaction equation, (20) are expressed such that they each inform explicitly all of "observables" before and after a pair production. In particular, (20) inform that both charges $(+e, -e)$ and spins $(\frac{\hbar}{2}, \frac{\hbar}{2})$ are present on their right-hand sides, but not the left-hand sides. And the external energy supply $2\varepsilon_{exc} = 2Mc^2$ is only to ascribe dynamical masses to the pair of vaculeon charges $+e, -e$ (which have zero rest masses), or equivalently, (dynamical) rest masses to the resulting IED particles in each reaction process, e, \bar{e} or p, \bar{p} . So the *charges* $+e, -e$ which carry a potential energy $V_{p_v n_v}(r_{n_v})$ at the particles' production as given by (18), and their *spins* $\frac{\hbar}{2}$'s which carry a kinetic energy, must *exist* in the vacuum, whence the *vaculeons* composing a vacuon, so as to satisfy the requirement of energy conservation. Similar discussion was made in terms of the pair annihilation in [2, 9, 13].

Supplemental remarks regarding the pair production: (i) *The resonance condition.* In mechanical terms, as follows from Sec. 2, the dielectric vacuum is induced with an elasticity in the presence of an external charge (q) nearby. And the electromagnetic (γ) wave, of a wavelength $\lambda_\gamma \sim 1.3 \times 10^{-15}$ or $\sim 2.4 \times 10^{-12}$ m, is an elastic wave propagated in the vacuum by means of the elastic deformations of the vacuum, or in other terms, of the oscillations of coupled oscillators each composed of (tremendously) many vacuons (of size $\sim 10^{-18}$ m each). So relative to the extensive γ wave, the pair of vaculeons p_v, n_v in a vacuon (the v_1 above) are just a minute point on a large oscillator. They will respond to the γ wave as one point, practically the only point in the large oscillator being in the (internal) mode of resonance absorption to the quanta $2\hbar\omega_r$ of the γ wave, assuming no other bound vaculeons in the large oscillator are dissociated to above level V_{vq0} .

(ii) The incident γ wave of energy $2\varepsilon_{exc}$ is an extensive electromagnetic wave train (as schematically shown in Figure 2c) of length L_φ and effective amplitude $A_{q2} = \frac{\sqrt{2}}{\sqrt{t_{\varphi 2.0}/(1/\omega)}} \mathcal{A}_{q1}$ [16]. Accordingly, the "absorption of $2\varepsilon_{exc}$ " is a gradual, continuous process spanning a total duration $t_{\varphi 1.0}$, in which the wave train front runs at the velocity of light c on to the two vaculeon charges $+e$ and $-e$ of v_1 , and be thereby absorbed by them (by a certain fraction) continuously. Two new waves of the same ω , and of amplitude A_{q1} each, are subsequently continuously re-emitted by the two charges, and then, together with the transmitted fraction, re-absorbed after reflecting back from surrounding walls.

(iii) At the end of one $t_{\varphi 1.0}$, two full wave trains (i.e. for the fraction $a_1 + a_2 = 1$) maintain the same L_φ , and same total $2\varepsilon = 2mc^2$, and $2p = 2\varepsilon/c = 2mc$ (i.e. the linear momentum, which is conserved in this sense) as the incident one. These two wave trains have now become the respective (internal) components of the (IED) particle and antiparticle just produced.

Acknowledgments

The author's research is privately funded by emeritus scientist P-I Johansson who has also given continued moral support for the author's researches. A focused elaboration on the solution for the vacuum potential in terms of the IED particle model presented in this paper was motivated by one of a wide scope of all essential questions put forward to the author at a seminar discussion during the author's visit to Professor I Lindgren at his Atomic Physics Group, Gothenburg Univ., Feb, 2011. An introduction prior to the visit is indebted to Professor B Johansson (Uppsala Univ.) The author expresses also thanks to a community of national and international distinguished physicists for giving moral support for the author's recent-year research, and to the organising chairman Professor C Burdik, chairman Professor H-D Doebner, the organisers and committee of the 7th Int Conf Quantum Theory and Symmetries (QTS 7) for facilitating the opportunity of communicating this research at the QTS 7, Prague, Aug., 2011.

Appendix A. Electromagnetic interaction between a vacuon and external charge

A.1 Interactions at larger distances up to a closest approach

As shown in Figure 2b (Sec. 4), the vacuon v_1 at $z = 0$ is polarised by the external charge $+q$ in the interstice B , moving from initial position say $z = \frac{bv_1}{\sqrt{2}}$ toward v_1 at a finite speed. We shall express the v_1 — $+q$ and v_1 — $-q$ interaction potentials in electromagnetic terms below, and shall do so by situating ourselves in the frame where the mass centre of v_1 is not moved during the interaction. (This frame approximately corresponds to the frame fixed to the vacuum if v_1 and its surrounding vacuons can not move freely due to attachment to a fixed matrix of charged particles, but their configuration may be locally deformed under the dynamical impact of q .) In this frame, the p_v and n_v vaculeons of the polarised vacuon v_1 are displaced from the fixed position $z = 0$ to $-\frac{d}{2}$ and $+\frac{d}{2}$. Since $r_{n_v} \gg \sigma$, we shall regard the p_v and q as point like and the n_v - spherical shell extensive in respect to their short range interactions.

$+q$ interacts with a charge element dq_1 on the extensive spherical shell of n_v by a Coulomb attraction $dF = \frac{dq_1 \cdot q}{4\pi\epsilon_o \ell}$. Integration over the entire shell gives the total attraction of $+q$ and n_v as [2] $F \doteq -\frac{u_1\sigma}{r_{n_v}} \left(\frac{r_{n_v}}{z}\right)^{n+1}$, with $n = 15.7$, which is strongly short ranged (whence a "strong force"). Accordingly $V_{n_v+q}^{coul} = -\frac{1}{2} \int_z^\infty F dz \doteq -\frac{u_1\sigma}{2r_{n_v}n} \left(\frac{r_{n_v}}{z}\right)^n$. Because of the simple symmetry of the n_v -shell with respect to $+q$, for a better physical transparency we below express this interaction alternatively by representing n_v effectively as two one-half charges

$\frac{e}{2}, \frac{e}{2}$ projected on the z axis at $-\bar{r}_{n_v}, +\bar{r}_{n_v}$, with $\bar{r}_{n_v} = r_v/2[2]$, as

$$V_{n_v+q}^{coul} = -\frac{u_1}{4} \left[\frac{\sigma}{z - (\bar{r}_{n_v} + \frac{d}{2})} + \frac{\sigma}{z + (\bar{r}_{n_v} - \frac{d}{2})} \right] = -\frac{u_1\sigma\eta}{2(z - \frac{d}{2})}, \quad \eta = \frac{1}{1 - (\bar{r}_{n_v}/(z - \frac{d}{2}))^2}. \quad (A.1)$$

In addition, $+q$ interacts with n_v similarly through n_v of a fractional charge gq as in (18) by a short range repulsion, $V_{n_v+q}^{rep} = \frac{u_1}{2}g \left(\frac{\sigma}{z - (r_{n_v} + \frac{d}{2})} \right)^N$. And, with the n_v -shell in between, $+q$ interacts with p_v by a Coulomb repulsion only, $V_{p_v+q}^{coul} = \frac{u_1}{2} \frac{\sigma}{z + \frac{d}{2}}$ for $z \geq 4\sigma$. Adding the terms above, we obtain the interaction potential energy of $+q$ with vacuon v_1 , and similarly of $-q$ with v_1 after corresponding sign changes, as

$$V_{v_1\pm q} = V_{n_v\pm q}^{rep} + V_{n_v\pm q}^{coul} + V_{p_v\pm q}^{coul} = \frac{u_1}{2} \left[g \left(\frac{\sigma}{z - (r_{n_v} \pm \frac{d}{2})} \right)^N \mp \frac{\sigma\eta}{(z \mp \frac{d}{2})} \pm \frac{\sigma}{(z \pm \frac{d}{2})} \right],$$

$$V_{v_1\pm q} = \frac{u_1}{2} \left[g \left(\frac{\sigma}{z - (r_{n_v} \pm \frac{d}{2})} \right)^N \mp \frac{\sigma(\eta - 1)}{z} - \frac{\sigma d(\eta + 1)}{2z^2} \right], \quad \eta = \frac{1}{1 - (\bar{r}_{n_v}/(z \mp \frac{d}{2}))^2}, \quad (A.2)$$

where (A.2b) is given after expanding the second and third terms of (A.2a) in $\frac{d}{2z}$ and retaining the respective two first leading terms. The last term in (A.2b), $-\frac{u_1\sigma d(\eta+1)}{4z^2}$, represents the interaction energy of the n_v vacuon dipole moment, $\mathbf{p}_{n_v} = ed\hat{z}$, with the static Coulomb field of charge q , $\mathbf{E}_q = \frac{u_1\sigma(\eta+1)}{2ez^2}\hat{z}$, and this may be directly obtained as $V_{dip\pm q} = \frac{1}{2}\mathbf{p}_{n_v} \cdot \mathbf{E}_q = -\frac{u_1\sigma d(\eta+1)}{4z^2}$. Since for small d there is always $\eta > (\text{ or } >>) 1$, at $z - \frac{3}{2} > \bar{r}_{n_v}$, $V_{dip\pm q}$ is thus an attraction for either $+q$ or $-q$. The second term in $V_{v_1\pm q}$ of (A.2b), $\pm \frac{\sigma}{(z \pm \frac{d}{2})} = V_{n_v\pm q}^{coul}$ is a main attraction term between v_1 and $+q$, and is a repulsion between v_1 and $-q$. The sum of the interactions of q with all surrounding vacuons up to an intermediate range, $\sum_i V_{v_i q}$, gives the $V_{v q}$ of Sec. 2.

As the graphical plots in Figure 3 b directly show, from larger z down to a closest approach at $z = r_v$, the potential V_{v_1+q} (solid curve) for the positive charge $+q$ is strongly negative, while V_{v_1-q} (dotted curve) for $-q$ is positive for a wide range of d value ($d = 0.01b_v$ for the plots).

A.2 Dynamical interactions after q, n_v closest approach

At about $z = r_v$, $+q$ and the segment n_v^{ef} of the n_v -shell (cf Figure 2c) are at closest approach. And the $+q$ - n_v interaction potential, $V_{n_v+q} = V_{n_v+q}^{rep} + V_{n_v+q}^{coul}$ as given by the sum of first two terms in (A.2a), shown by the dotted curve 3 in Figure 3a, rises rapidly.

From $z = r_v$ downward, $+q$ continues to move toward p_v , now together with n_v while impressing on the segment n_v^{ef} (which has the coordinate $z' = z - 2\sigma$) of n_v a constant repulsion $V_{n_v+q}^{rep}(z - z') = g(\frac{\sigma}{2\sigma})^N = g(\frac{1}{2})^N$ (with the steep sector of the dotted curve 3 sweeping across the region, ending at curve 3'). In addition, $+q$ interacts with n_v by a Coulomb potential $V_{n_v+q}^{coul}(z)|_{z=r_{n_v}} = -\frac{u_1\sigma\eta}{2(r_{n_v}-d/2)}$ as given after (A.1); and with p_v by the $V_{p_v+q}^{coul} = \frac{u_1\sigma}{2(z+d/2)}$ as before. p_v interacts with n_v , as a very crude approximation here, by the constant Coulomb potential $V_{p_v n_v}(r_{n_v}) = -\frac{u_1}{2} \frac{\sigma}{r_{n_v}} = -1799.9 \text{ MeV}$, and with the segment n_v^{ef} of n_v by a short range repulsion $V_{p_v n_v}^{rep}(z') = \frac{u_1}{2}g(\frac{\sigma}{z-2\sigma})^N$. Adding the respective terms above, the total potentials of p_v and n_v as functions of the coordinate z of $+q$ are

$$V_{p_v n_v+q}(z) = V_{p_v n_v}^{rep}(z') + V_{p_v n_v}^{coul}(r_{n_v}) + V_{p_v+q}^{coul}(z) = \frac{u_1}{2} \left[g \left(\frac{\sigma}{z - 2\sigma + \frac{d}{2}} \right)^N - \frac{\sigma}{r_{n_v}} + \frac{\sigma}{(z + \frac{d}{2})} \right],$$

$$(A.3)$$

$$\begin{aligned} V_{n_v p_v + q}(z) &= V_{n_v p_v}^{rep}(z') + V_{n_v + q}^{rep}(z - z') + V_{p_v n_v}^{coul}(r_{n_v}) + V_{n_v + q}^{coul}(z - z') \\ &= \frac{u_1}{2} \left[g \left(\frac{\sigma}{z - 2\sigma + \frac{d}{2}} \right)^N + \left(\frac{1}{2} \right)^N - \frac{\sigma}{r_{n_v}} - \frac{\sigma\eta}{z - \frac{d}{2}} \right]. \end{aligned} \quad (A.4)$$

These are plotted by the dashed curve 2 and dotted curves 3-3' in Figure 3a. When $+q$ is at $z = z' + 2\sigma = 4\sigma - \frac{d}{2}$, n_v^{ef} is at $z' = z - 2\sigma = 2\sigma - \frac{d}{2}$ and touches p_v , producing on p_v a strong short range repulsion $V_{p_v n_v}^{rep}(z' = 2\sigma - \frac{d}{2}) = \frac{u_1}{2} g \left(\frac{\sigma}{z - 2\sigma + d/2} \right)^N$.

Appendix B. Diffusion current of complex fluid

Let $\rho_A(z, t)$ be the density of a real fluid in flow motion at velocity v in z direction with a flow rate $j_A = \rho_A v$. j_A may be alternatively written as a diffusion current $j_A = -D_A \nabla \rho_A$ (Fick's first law), where D_A is a real diffusion constant; and j_A is positive in the direction in which the density gradient decreases. Let ρ_A be written as $\rho_A = \mathcal{A}' \mathcal{A}$ where $\mathcal{A}', \mathcal{A}$ are two arbitrary differentiable real functions of z, t . Then

$$j_A = -D_A [(\nabla \mathcal{A}') \mathcal{A} + \mathcal{A}' (\nabla \mathcal{A})]. \quad (B.1)$$

If now it is a "complex" fluid of density $\rho_q = \psi_q^* \psi_q$, where $\psi_q(z, t) = e^{i\omega t} \phi_q(z)$ and ψ_q^* are the complex functions as in Sec. 2, and we want to write down a positive diffusion current j_q associated with ρ_q on an equal footing with (B.1), certain transformations must be involved as we proceed as follows. Firstly, since $z(t) = v_q t$, v_q being the flow velocity in z direction, thus $e^{i\omega t} = e^{i\omega z/v_q}$; accordingly $\psi_q(z, t(z)) \rightarrow \psi_q(z)$, $\psi_q^* \rightarrow \psi_q^*(z)$, and $\rho_q \rightarrow \rho_q(z)$; i.e., z is now an explicit independent variable of ρ_q similarly as of ρ_A in (B.1). We further define (for reason to become evident in the end) an imaginary diffusion constant, $D_q = i|D_q|$. We can now make three immediate substitutions of variables in (B.1) with corresponding ones for ρ_q , in such a way that each term is ensured real and having a correct sign so as to finally achieve a j_q in accordance with the definition of (B.1):

$$D_A \rightarrow |D_q| = -iD_q, \quad \mathcal{A}' \rightarrow \psi_q^*, \quad \mathcal{A} \rightarrow \psi_q. \quad (B.2)$$

The derivatives of ψ_q and ψ_q^* will however introduce an imaginary index i and sign into the coefficients, as $\frac{1}{\psi_q^*} \nabla \psi_q^* = -ik$, $\frac{1}{\psi_q} \nabla \psi_q = ik$. To obtain their "positive and real" values we rotate the two functions in the complex plane by angles $+\frac{\pi}{2}$ and $-\frac{\pi}{2}$, thus

$$\nabla \mathcal{A}' \rightarrow i \nabla \psi_q^*, \quad \nabla \mathcal{A} \rightarrow -i \nabla \psi_q; \quad -\nabla \rho_A \rightarrow -|\nabla \rho_A| = -[(i \nabla \psi_q^*) \psi_q + \psi_q^* (-i \nabla \psi_q)] \quad (B.3)$$

With (B.2), (B.3) in (B.1), we obtain

$$j_q (= -|D_q| |\nabla \rho_q|) = -(-iD_q) [(i \nabla \psi_q^*) \psi_q + \psi_q^* (-i \nabla \psi_q)] = -D_q [(\nabla \psi_q^*) \psi_q - \psi_q^* (\nabla \psi_q)]. \quad (B.4)$$

Appendix C. Radiation emission time by quasi harmonically oscillating charge

Suppose that (i) the F_{ext} in (3), Sec. 2, is not zero but is equal to a radiation damping force, $F_{ext} = F_{rad} = -\omega_r \mathfrak{M}_q \frac{d\mathcal{U}_q}{dt}$, where ω_r is a radiation damping factor, (ii) $(\omega_r/\omega)^2 \ll 1$, so the equations of motion and the solutions of Sec. 2 continue to hold over a finite time interval in which damping of amplitude is negligible, whence a quasi stationary radiation, and (iii) we restrict as before (Sec. 2) to the excitations which create matter particles only. Then, the energy solution for (3) combined with (2) of the now quasi-harmonically oscillating charge is at any time t_s given as, dropping a term $\frac{1}{2} \hbar \omega$ similarly as in (6),

$$\varepsilon'_{qn}(t_s) = e^{-\omega_r t_s} \varepsilon_{qn}, \quad \varepsilon_{qn} = n \hbar \omega, \quad n = 1, 2, \dots \quad (C.1)$$

If at initial time $t_s = 0$ the charge is at level n and just begins to emit radiation, and after a time $t_s = t_{\varphi n.n-1}$ it has emitted one entire energy quantum $\Delta\varepsilon_{qn.n-1} = n\hbar\omega - (n-1)\hbar = \hbar\omega$, whence transforming to level $n-1$, the energy reduction given after (C.1) is

$$\Delta\varepsilon'_q(t_{\varphi n.n-1}) = n\hbar\omega(1 - e^{-\omega_r t_{\varphi n.n-1}}). \quad (C.2)$$

But $\Delta\varepsilon'_q(t_{\varphi n.n-1}) = \Delta\varepsilon_{qn.n-1}$; or, $n\hbar\omega(1 - e^{-\omega_r t_{\varphi n}}) = \hbar\omega$. This gives

$$t_{\varphi n.n-1} = -\frac{1}{\omega_r} \ln \frac{n}{n-1}. \quad (C.3)$$

References

- [1] Nakamuura K *et al* (Particle Data Group) 2010 *J. Phys. G: Nucl. Part. Phys.* **37** 075021; P J Mohr 2008 CODATA recommend values of the fundamental physical constants: 2006" *Rev. Mod. Phys.* **80**, 633-730; D. Griffith 1987 *Introduction to elementary particles* (Harper and Row Publisher); D Brune, B Forkman, B Persson 1984 *Nuclear Analytical Cemetery* (Studentlitteratur, Lund); E Rutherford 1919 *Phil. Mag.* **37** 581; J J Thomson 1897 *Phil Mag* **44** 293.
- [2] Zheng-Johansson J. X. and P-I. Johansson 2006 *Unification of Classical, Quantum and Relativistic Mechanics and of the Four Forces* (Nova Sci. Pub. Inc., N. Y.). Zheng-Johansson, J.X. 2003 Unification of Classical and Quantum Mechanics & The Theory of Relative Motion *Bullet Amer. Phys. Soc.* **G35.001** General Physics, March; Zheng-Johansson, J.X., P-I Johansson, (Feb 24) 2003 Unification Scheme for Classical and Quantum Mechanics at All Velocities (I) fundamental construction of material particles, submitted to *Proc Roy Soc Lond.*
- [3] Zheng-Johansson, J. X. 2006 *Inference of Basic Laws of Classical, Quantum and Relativistic Mechanics from First-Principles Classical-Mechanics Solutions* (Nova Sci. Pub., Inc., N. Y.).
- [4] Zheng-Johansson J. X. and P-I. Johansson 2006 Inference of Schrödinger equation from classical mechanics solution *Suppl. Blug. J. Phys.* **33**, 763, *Quantum Theory and Symmetries* **IV.2**, ed. V.K. Dobrev (Heron Press, Sofia), p763 (*Preprint* arxiv:physics/0411134v5).
- [5] Zheng-Johansson J. X. and P-I. Johansson 2006 Developing de Broglie wave *Prog. Phys.* **4**, 32 (*Preprint* arxiv:physics/0608265).
- [6] Zheng-Johansson J. X. and P-I. Johansson 2006 Mass and mass-energy equation from classical-mechanics solution *Phys. Essays* **19**, 544 (*Preprint* arxiv:physics/0501037).
- [7] Zheng-Johansson J. X. 2006 *Prog. Phys.* **3**, 78 (*Preprint* arxiv:physics/060616).
- [8] Zheng-Johansson J. X. 2008 Dirac equation for electrodynamic model particles *J. Phys: Conf. Series* **128**, 012019, *Proc. 5th Int. Symp. Quantum Theory and Symmetries*, ed. M. Olmo (Valladolid, 2007).
- [9] Zheng-Johansson J. X. 2007 Vacuum structure and potential *Preprint* arxiv:0704.0131.
- [10] Zheng-Johansson J. X. 2006 Dielectric theory of the vacuum, *Preprint* arxiv:physics/0612096.
- [11] Zheng-Johansson J. X., P-I. Johansson, R. Lundin 2006 Depolarisation radiation force in a dielectric medium. its analogy with gravity, *Suppl. Blug. J. Phys.* **33**, 771; J. X. Zheng-Johansson and P-I. Johansson, Gravity between internally electrodynamic Particles, *Preprint* arxiv:physics/0411245.
- [12] Zheng-Johansson J. X. 2008 Doebner-Goldin Equation for electrodynamic model particle. The implied applications *Preprint* arxiv:0801.4279, Talk at 7th Int. Conf. Symm. in Nonl. Math. Phys. (Kyiv, 2007).
- [13] Zheng-Johansson J. X. 2010 Internally electrodynamic particle model: its experimental basis and its predictions *Phys. Atom. Nucl.* **73** 571-581 (*Preprint* arxiv:0812.3951), *Proc Int 27th Int Colloq Group Theory in Math Phys.* ed. G Pogossyan (Ireven, 2008).
- [14] Zheng-Johansson 2010 Self interference of single electrodynamic particle in double slit *Preprint* arxiv:1004.5000; Talk at *Proc. 6th Int. Symp. Quantum Theory & Symm.* (Lexington, 2009).
- [15] Zheng-Johansson J. X. 2010 Quantum-Mechanical Probability of IED Particle(s) *Preprint* arxiv: 1011.1344. Talk at 28th Int. Colloq. Group Theory in Math. Phys. (Newcastle, 2010).
- [16] Zheng-Johansson J. X. 2011 Dynamics and radiation of harmonically oscillating charge of IED particle from a unified treatment (internal, 2011).
- [17] The experimentally measured upper bound of electromagnetic radiation frequency is $\nu_o \sim 5 \times 10^{25}$ 1/s (see e.g. C Nordling and J Österman, *Physics Handbook* for Sci Eng, 6th Ed, Studentlitteratur, 1999, p53, Table 4.2); this gives the minimum wavelength $\lambda_o = \frac{c}{\nu} = 6 \times 10^{-18}$ m. A vacuum continuum able to propagate a wave of this shortest-wavelength should have a spacing b_v at least several times smaller than λ_o . Taking the scaling factor to be 6 here, we have $b_v = \lambda_o/6 = 1 \times 10^{-18}$ m.
- [18] Merzbacher E. 1970 *Quantum Mechanics* (John Wiley and Sons, Inc.) p. 57.